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GENETIC DIVERGENCE AND COMBINING ABILITY STUDIES FOR EXPLOITATION OF HETEROSIS IN PAPRIKA (*CAPSICUM ANNUUM* L)

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ABSTRACT

Ninety four paprika accessions were evaluated for seventeen different characters for variability, heritability, genetic advance as percent of mean and genetic divergence. Higher phenotypic and genotypic coefficient of variation, heritability coupled with high genetic advance was observed for number of fruits per plant including fresh fruit yield per plant, dry fruit yield per plant, 100 seed weight, Number of seeds per fruit, capsanthin, capsaicin and oleoresin content. This indicates the higher magnitude of variability for these traits and consequently more scope for their improvement through selection. Plant height, plant spread, and fruit diameter exhibited moderate PCV and GCV estimates suggesting the possible role of environment in expression of these characters. Mahalanobis D2 analysis classified the genotypes into 10 clusters indicating considerable genetic diversity. Forty crosses were attempted in line x tester design using the diverse parents belonging to different groups. Among 14 parents, 7 parents have significant positive gca effect for dry fruit yield per plant with the maximum observed in LCA-428 (134.49) followed by LCA-436 (111.51) and LCA-432 (53.45).

These parents had significant gca effects for number of fruits per plant, 100 seed weight, number of seeds per fruit, capsanthin content, days to 50 per cent flowering, days to maturity, fresh fruit yield per plant, weight of dry stalk less fruits per plant. The parent LCA-422 exhibited the highest negative gca effect for days to 50 per cent flowering, days to maturity, and significant gca effect in desired direction for number of seeds per fruit, 100 seed weight, and capsanthin content. LCC-422 is useful for incorporating earliness, low pungency and high color. Best five hybrids with high per se performance for fresh fruit yield per plant were LCA-436 x CA-960 (279.7), LCA-436 x Byadagi Dabbi (207.39), LCA-422 x CA-960 (217.19), LCA-431 x Byadagi Dabbi (220.3) and LCA-414 x Byadagi Dabbi (175.06). These hybrids also exhibited high sca effects for total yield per plant and yield components. Hybrids LCA-436 x CA-960 and LCA-436 x Byadagi Dabbi also exhibited significant sca effects for plant spread, number of fruits per plant, 100 seed weight, number of seeds per fruit and days to maturity. The crosses LCA-437 x KTPL-19 and LCA-437 x CA-960 had significant sca effects in desirable direction for capsaicin content. The cross LCA-414 x KTPL-19 considered the best as it has desirable sca effects for quality (capsaicin and capsanthin). The crosses LCA-436x CA-960, LCA-436 x Byadagi Dabbi, LCA-422 x CA-960, LCA-414 x Byadagi Dabbi were best for both yield and quality.

KEYWORDS: Paprika, Genetic Divergence, Combining Ability, Hybrid, Capsanthin

INTRODUCTION

Paprika refers to certain types of chilli (*Capsicum annuum* L.*)* grown mainly for value-added powder and oleoresins for imparting color, flavor and aroma in various food preparations. The term paprika used by international spice traders for non pungent (sweet) red capsicum powder has great commercial importance worldwide. This ground product is the basic material for producing capsicum oleoresin. The demand for paprika oleoresin as a coloring agent has increased in international market especially in Europe and USA due to ban on artificial coloring substances (Joshi *et al* 1995). Globally, chilli and paprika (dry) are grown on a total area of 1.94 million hectares with global production at 3.35 million tonnes in 2011.

The global productivity of the chilli and paprika (dry) was 1.73 metric tonnes/ha. The value of the total chilli and paprika was 3.42 million USD. India is the world's leading producer occupying an area of 0.86 million hectares with a production of 1.5 million tonnes and productivity of 1.66 metric tonnes/ha (FAOSTAT, 2013). Importance of this crop is increasing to meet international demands. Developing good paprika hybrids will help the industry. Improvement in both quantitative as well as qualitative traits needs precise information on the nature and degree of genetic divergence, which helps in choosing the right parents for an efficient breeding programme.

MATERIALS AND METHODS

The experiment was conducted during the June-May months of 2005 to 2007 as part of doctoral research (Surya Kumari, 2007) at Regional Agricultural Research Station, Lam Farm, ANGRAU, Guntur, India (16°18' N and 80° 29'E). The experimental soil type was vertisols. The soil was medium in available N and available P_2O_5 and high in exchangeable K_2O. The present investigation was carried out with 94 paprika accessions from diverse geographical origin within India. The germplasm was studied for genetic variability, heritability, genetic advance as per cent of mean, genetic divergence, character association and path analysis, heterosis and combining ability for quality and economic characters.

The data were recorded on 17 characters viz., plant height (cm), plant spread (cm),days to 50 per cent flowering, days to maturity, number of fruits per plant, fruit length (cm), fruit girth (cm),fruit shape index, fresh fruit yield per plant (g), dry fruit yield per plant (g),weight of dry stalk less chillies per plant (g),number of seeds per fruit, 100- seed weight (g), oleoresin content (%), capsanthin content (EOA colour value) and capsaicin content (%). Data was statistically analysed using methods described by Panse and Sukhatme (1967), Burton and De vane (1953), Lush (1940), Johnson *et al*., (1955), Mahalanobis (1928), Jackson (1991), Anderberg (1993) and Rao (1952).

RESULTS AND DISCUSSIONS

The analysis of variance in the 94 paprika genotypes indicated highly significant differences among the genotypes for all 17 quantitative and qualitative characters studied, indicating the existence of adequate genetic variability among the genotypes studied. This was in accordance with the reports of Sarma and Roy (1995), Smitha (2005) and Biswadipchatterjee (2006). High heritability coupled with high genetic advance as per cent of mean were observed for all the traits except days to 50 percent flowering and days to maturity indicating the influence of additive gene effects on the other 15 characters and hence simple selection may be effective for improving these traits.

Higher PCV and GCV were observed for number of fruits per plant, fresh fruit yield per plant, dry fruit yield per plant, 100 seed weight, number of seeds per fruit, capsanthin content, capsaicin content and oleoresin content indicating the

higher magnitude of variability for these traits and consequently more scope for their improvement through selection. Plant height, plant spread and fruit diameter exhibited moderate PCV and GCV estimate suggesting the possible role of environment in influencing these characters (Table 1).

The findings of multivariable (D square) analysis showed the random distribution of 94 paprika genotypes into ten clusters and there was no association of genetic diversity with geographical diversity of parents. Principal component analysis identified three principal components (PCs), which contributed 78.47 per cent of cumulative variance. Dendrogram obtained by cluster analysis showed the sub-grouping of genotypes within the clusters, which was not possible through D2 analysis. Similar results were reported by Usharani (1996) and Biswadipchatterjee (2006) where 7 principal components were formed to describe the maximum variance of the data set. Based on the inter- and intracluster distance among the groups, fourteen parents were selected 3 each from cluster 1X and X and one each from clusters I, II, III, IV, V, VI, VII and VIII, keeping in mind the characters contributing for divergence soas to obtain better and desirable seggregants (Table 2).

Among 14 parents, 7 parents have significant positive gca effect for dry fruit yield per plant with the maximum observed in LCA-428 (134.49) followed by LCA-436 (111.51) and LCA-432 (53.45). These parents had significant gca effects for number of fruits per plant, 100 seed weight, number of seed per fruit, capsanthin content days to 50 per cent flowering, days to maturity, fresh fruit yield per plant, weight of dry stalk less fruits per plant. The parent LCA-422 exhibited the highest negative gca effect for days to 50 per cent flowering, days to maturity and significant gca effect in desired direction for number of seeds per fruit, 100 seed weight, and capsanthin content. This parent will, therefore, be of use in breeding earliness and less pungent and more coloured paprika.

For all the 17 characters studied except for fruit length, number of seeds per fruit, and 100 seed weight, about 50 percent of the crosses recorded significant heterosis over the mid- parent indicating that both additive and non-additive type of gene action were of equal importance for these characters. For characters like plant height, fresh fruit yield per plant, dry fruit yield per plant, days to maturity and number of fruits per plant, the majority of the hybrids showed significant heterosis explaining the non-additive gene action, whereas for character like seeds per fruit, seed weight, capsaicin, only less than 50 per cent of crosses showed significant mid- parent heterosis, which meant that for these characters additive gene action was involved to a greater extent than non-additive type of gene action. But the combining ability analysis revealed more of SCA variance than GCA variance except for capsanthin content indicating that non-additive type of gene action was predominant for all the characters studied and additive gene effect for capsanthin content (Table 3).

The superiority of the hybrids in crosses was estimated over mid-parent, better parent and standard check for all the 17 characters studied. The cultivar, Byadigi Kaddi was selected as a standard check. For high productivity the crosses LCA-436 x CA-960, LCA-428 x KTPL-19, LCA-428 x LCA-424, LCA-436 x KTPL-19, LCA-432 x KTPL-19 were identified as the best heterotic combinations. They showed significant positive standard heterosis ranging from 299.3 to 349.8 per cent yield. These results indicated that the high productivity of these hybrids was associated with plant height, plant spread and number of fruits per plant. Further the hybrids LCA-436x KTPL-19, LCA-436x CA-960 also registered very low capsaicin content and good colour value compared to the check Byadigi kaddi. The hybrid LCA-437 x CA-960 is considered to be the best heterotic combination, which recorded high oleoresin content (16.7 per cent) maximum capsanthin content (7249 EOA units) and minimum capsaicin content (0.09%) (Table 4)

The cross LCA-414 x CA-960 and LCA-436 x B. Dabbi involved positive x negative general combiners with common parent LCA-436 having highest and significant gca effect, demonstrated its value as good general combiner for the total yield per plant. Similarly the crosses LCA-437 x KTPL-19 and LCA-437 x CA-960 had significant sca effects in desirable direction for capsaicin content. The parents of the crosses were positive x negative general combiners. However, it can be observed that the cross LCA-414 x KTPL-19 can be considered the best as it has desirable sca effects for quality parameters both capsaicin and capsanthin. Similar results were reported by Gaddagimath (1992) Patel et al. (1997), Jagadeesh (2000) and Nandadevi et al (2003).

CONCLUSIONS

It can be concluded from the study that the lines LCA-414, LCA-422, LCA-431 and LCA-436 and the tester KTPL-19 and B. Dabbi gave the best F1 hybrids for potential yield. For quality parameters the lines LCA-433 and LCA-437 along with the tester KTPL-19 gave the best F1 hybrid. Multiple hybridization by combining most of the desired horticultural traits with high yield and best quality parameters can be attempted as the lines exhibited considerable divergence and high magnitude of non-additive gene action for most of the economic characters.

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APPENDICES

Table 1: Genetic Parameters in Respect of Quantitative Traits in Paprika

Characters	Mean	σ^2g	σ^2v	GCV (%)	PCV (%)	h^2 (%)	Genetic Advance 5%
Plant height (cm)	95.2	199.6	210.2	14.8	15.2	95.0	28.4
Plant Spread (cm)	124.9	677.2	694.6	20.8	21.1	97.5	52.9
Days to 50% flowering	75.0	15.5	17.9	5.2	5.6	87.0	7.6
Days to maturity	110.0	81.6	85.1	8.2	8.4	95.9	18.2
Fruits/plant	126.0	1674.3	1712.2	32.5	32.8	97.8	83.4
Fruit Length (cm)	8.6	4.0	4.4	22.7	24.4	86.7	3.7
Fruit girth (cm)	2.3	1.8	2.0	28.6	30.6	87.5	2.6
Fruit shape index	3.7	0.6	0.7	37.0	40.1	85.1	1.4
Fresh fruit weight/plant (g)	517.7	33819.0	33892.0	35.5	35.6	99.8	378.4
Dry fruit weight/plant (g)	160.4	2412.0	2465.0	30.6	31.0	97.8	100.1
Recovery % (fresh to dry)	31.8	25.1	27.7	15.7	16.5	90.6	9.8
Weight of dry stalk less fruit (g)	124.6	1244.4	1271.4	28.3	28.6	97.9	71.9
Seeds/fruit	71.5	894.1	915.1	41.8	42.3	97.7	60.9
Test (100 seed) weight (g)	0.5	0.1	0.1	60.1	61.8	94.6	0.5
Oleoresin (%)	8.1	8.9	9.0	36.7	36.9	99.2	6.1
Capsanthin (EOA)	33625	388379000	392060600	58.6	58.9	99.1	40406
Capsaicin (%)	0.2	0.0	0.0	39.8	40.3	97.6	0.2

*Genotypic variation σ^2g, phenotypic variation (σ^2v),

Genotypic coefficient of variation GCV (%),

Phenotypic Coefficient Variation PCV (%), Broad Sense Heritability % (h^2).

Table 2: Cluster Groups and Characters Considered for Selection for Generating F1 Hybrids

Cluster Number	Selected Genotypesin Respective Clusters	Characters Considered for Selection
I	Byadigi Dabbi	Low capsaicin content
II	LCA 428	Less number of seeds per fruit and low test weight.
III	KTPL19	High Oleoresin content and earliness
IV	LCA 422	Low capsaicin content
V	LCA 434	High seed content and test weight

Table 2: Contd.,

VI	LCA 414	Maximum fruit length
VII	LCA 433	Maximum plant spread and desirable fruit shape
VIII	CA960	Maximum fruit diameter and minimum capsaicin Content
IX	LCA 427, LCA 436 and LCA 424	High colour values with maximum capsanthin content.
X	LCA 431, LCA 432 and LCA 437	Maximum plant height, maximum. Number of fruits per plant, maximum fresh fruit weight, dry fruit weight and stalk less chilli weight per plant.

Table 3: General and Specific Combining Ability Variances and Genetic Components for 17 Characters in Paprika (*Capsicum Annuum* L)

Characters	Variance Due to GCA	Variance Due to SCA	COV (FS) L x T	F = 1		
				V_A	V_D	V_A / V_D
Plant height (cm)	40.09	87.37	264.94	80.17	87.37	1.08
Plant Spread (cm)	157.50**	930.03**	1585.86	315.61	930.03	2.95
Days to 50% flowering	2.1940**	17.845**	27.27	4.388	17.845	4.15
Days to maturity	4.249**	48.96**	66.32	8.498	48.96	5.76
No. of Fruits/Plant	1161.26**	2269.31	7190.30	2322.5	2269.3	0.98
Fruit Length (cm)	0.748**	2.084**	2.100	1.495	2.084	1.39
Fruit girth (cm)	0.012**	0.233**	0.233	0.025	0.23	9.2
Fruit shape	0.184**	0.6186**	1.401	0.368	0.6186	1.68
Fresh fruit wt/Pt (g)	15349.28**	25446.14**	90392.74	30699	25446	0.83
Dry fruit wt/pt (g)	2178.46**	2954.648**	12175.16	4356.91	2954.65	0.68
Recovery (%)	1.4927**	7.8219**	14.309	2.986	7.8219	2.62
Weight of Stalk less chillies (g)	1971.328**	2159.67	10518.88	3942.66	2159.67	0.55
No. of seeds /Fruit	-33.089	425.704**	279.63	+66.18	425.73	+6.43
100 seed wt (g)	0.006**	0.0132**	0.0385	0.0121	0.0113	0.94
Oleoresin content (%)	0.283**	3.2598**	4.414	0.567	3.2598	5.74
Capsanthin content (EOA)	66733047	327306	8261.90	133466094	32730	0.0024
Capsaicin content (%)	0.0013**	0.0088**	0.088	0.0026	0.0088	3.38

Table 4: Heterosis Range for 17 Quantitative Traits in Paprika

S No.	Characters	Heterosis (range)		
		Mid Parent	Better Parent	Standard Check
1.	Plant height (cm)	-30.87 to 38.49	-35.96 to 22.63	-16.52 to 59.82
2.	Plant spread (cm)	-1.30 to 64.56	-2.72 to 61.40	-4.40 to 191.8
3.	Days to 50% flowering	-23.08 to 13.95	-28.57 to 12.09	-5.56 to 35.00
4.	Days to maturity	-22.83 to 9.57	-27.05 to 3.28	-11.59 to 25.17
5.	No. of fruits per plant	-69.54 to 56.03	-74.90 to 27.48	-1.31 to 330.5
6.	Fruit length (cm)	-46.53 to 14.53	-49.79 to 14.04	-48.71 to 9.28
7.	Fruit girth (cm)	-38.38 to 84.81	-41.84 to 67.82	1.76 to 186.27
8.	Fruit shape index (L/B)	-59.90 to 64.24	-69.14 to 36.70	-78.01 to –1.79
9.	Fresh fruit wt./plant (g)	-59.33 to 73.61	-62.67 to 77.82	0.5 to 349.84
10.	Dry fruit wt./plant (g)	-65.40 to 57.70	-68.16 to 82.10	14.68 to 51.61
11.	Fresh to dry recovery (%)	-14.94 to 38.23	-15.17 to 41.68	-38.87 to 31.39
12.	Weight of dry stalk less chilli (g)	-72.65 to 74.55	-74.46 to 77.40	-26.46 to 28.70
13.	No. of seeds per fruit	-34.46 to 87.27	-39.49 to 83.85	-53.91 to 17.39
14.	100 seed weight (g)	-51.2 to 96.9	-57.32 to 59.45	-60.85 to 62.77
15.	Oleoresin content (%)	-51.46 to 42.86	-56.97 to 38.16	-46.85 to 62.77
16.	Capsanthin content (EOA)	-72.28 to 52.76	-77.82 to249.31	-64.96 to 73.86
17.	Capsaicin (%)	-49.06 to222.73	-65.12 to 140.68	-57.38 to 32.79

MP: Mid Parent

BP: Better Parent

SC: Standard Check

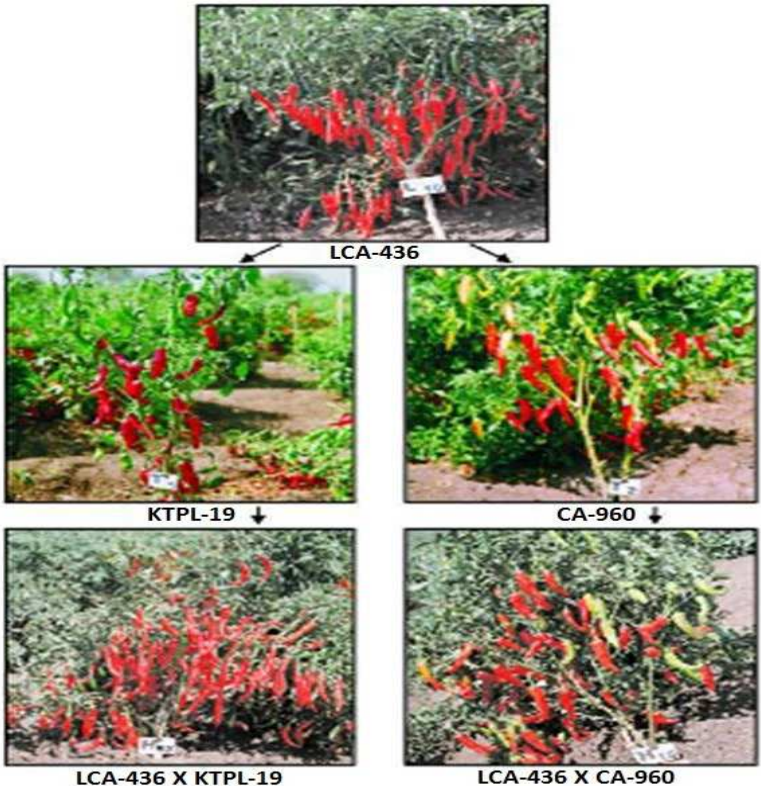

Figure 1: Paprika Hybrids with High Yield Potential

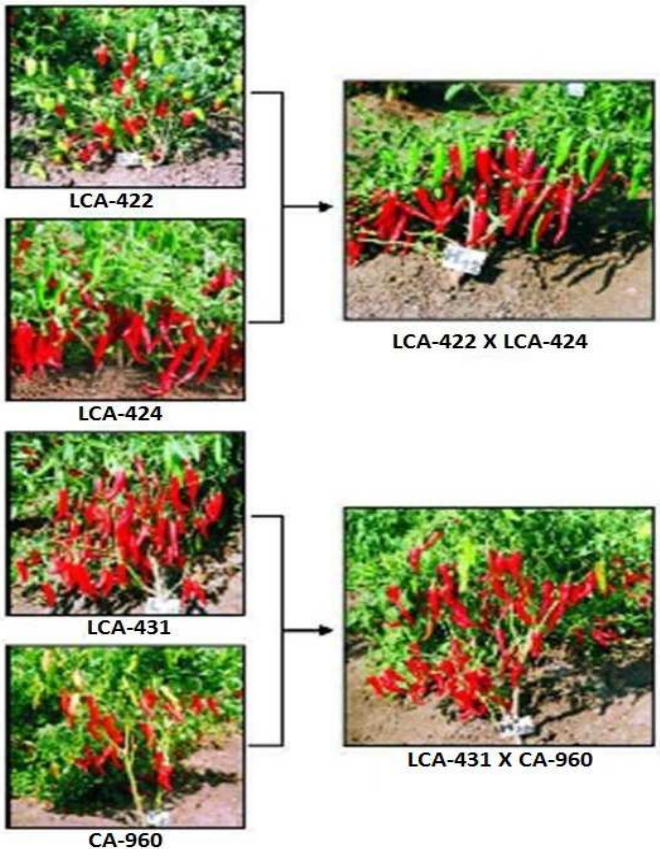

Figure 2: Paprika Hybrids with High Capsaicin Content

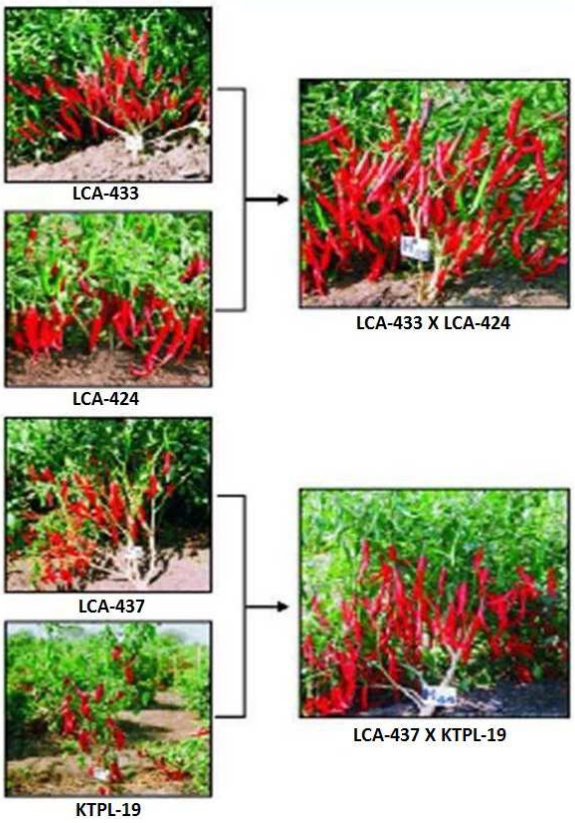

Figure 3: Paprika Hybrids with Capsanthin

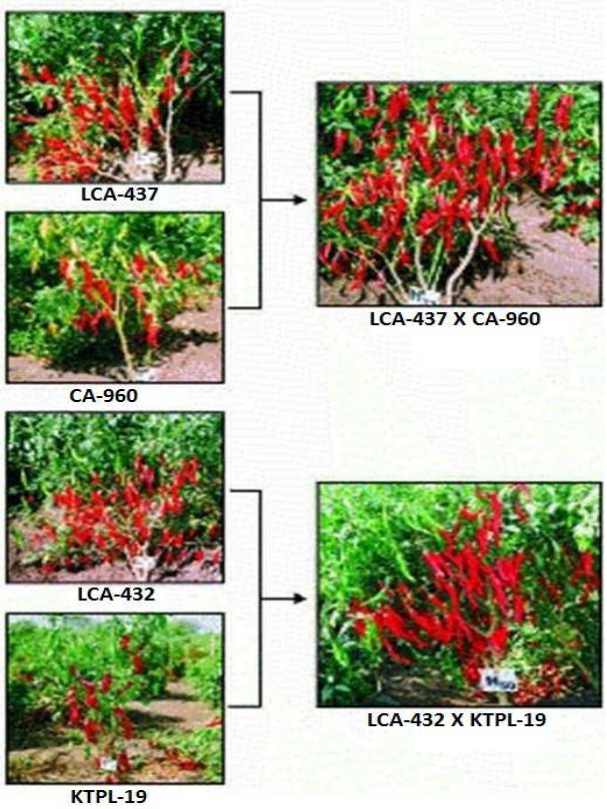

Figure 4: Paprika Hybrids with High Oleoresin Content